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Another argument against fundamental scalars

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A number of arguments have been given (Farhi and Jackiw 1982) against the presence of scalar fields in an action describing basic interactions at the fundamental level. Firstly, no Higgs scalar of the standard electro-weak theory of Weinberg and Salam has been found, whereas one expects at least one such scalar below 1 TeV (Lee *et al* 1977, Dicus and Mathur 1973). Presence of scalars increases the number of free parameters of the theory via their self-couplings and Yukawa couplings. Also, they can (in sufficiently large numbers) easily spoil asymptotic freedom (Gross 1975) which is at the heart of gauge unification. Presence of scalar fields in Grand unified theories and weak electromagnetic theories create problems of fine-tuning of certain fundamental parameters (Susskind 1979).

In this work, we wish to present another argument, perhaps not as strong, which is based on the inclusion of interaction with external gravity into a theory describing strong, electromagnetic and weak interactions. The argument is related to the basis of the common belief which favours a renormalizable action against a non-renormalizable action as a candidate for a fundamental theory. As is well-known, a renormalizable theory requires fewer experimental inputs ; for this reason and because of additional consequences of renormalizability, renormalizable theories have greater predictive power as compared to non-renormalizable theories. This is taken as a theoretical reason for favouring renormalizable theories over non-renormalizable theories.

A similar argument can be given to favour theories not containing fundamental scalars, an argument which involves the consideration of their interaction with external gravity. This argument is based on certain recent results described below.

It is known from the work of Freedman *et al* (1974) that in renormalizable theories not containing scalars, there exist energy-momentum tensors which are derivable from the minimal Einstein action and which are finite to all orders of perturbation theory. As a result, interaction with *external* gravity can be incorporated into such theories via the minimal Einstein action and this action leads to finite Green's functions to all orders of perturbation theory, *once the flat-space renormalizations are carried out.* Thus, the only experimental inputs that are needed for obtaining finite Green's functions, with external gravity included, are those needed for the renormalizations in flat space-time. The same situation exists in $\lambda\phi^4$ theory (or scalar theories with a *single* coupling constant) as known from Collins' work (1976a, 1976b) ; but such a theory *by itself* is hardly a candidate for a theory of fundamental interactions. A theory of fundamental interactions containing scalar fields necessarily contains two or more coupling constants. Recently, we (Joglekar and Misra 1988, 1989) have analysed energy-momentum tensors in all the renormalizable theories with scalar field (s) and two coupling constants.

In such theories, in order to obtain finite matrix elements for the energy-momentum tensor derived from the minimal Einstein action, an improvement term (Callan et *al* 1971) is needed. This improvement term is derivable from an addition to the minimal Einstein action of the *form* $\frac{1}{2}K_0\int R\phi^2 d^n x$. In other words,

$$S = S_{\min} + \frac{1}{2}K_0 \int R\phi^2 d^n x \tag{1}$$

The conclusion of our analysis in the case of these theories is that K_0 is necessarily *independently* renormalized ; requiring an additional experimental input in the form of root-mean-square mass radius of scalar particle (s) (Freedman and Weinberg 1974). This conclusion can be easily generalized to the theories containing scalar field (s) and more than two coupling constants.

Thus, the inclusion of external gravity into renormalizable theories containing scalar fields and two or more coupling constants need extra renormalization conditions and hence extra experimental inputs as compared to the renormalizable theories not containing scalars and hence have less predictive power. This makes the renormalizable theories without scalars seem *somewhat superior* as candidates for fundamental interactions. Thus a theory of fundamental interaction without scalars, incorporating dynamical symmetry breaking, seems more desirable when one considers interactions with external gravity (this being one among many other more important reasons).

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